Journal of Forensic and Legal Medicine 17 (2010) 388–391

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original Communication

Unintentional carbon monoxide poisoning in Northwest Iran: A 5-year study

Jalil Nazari PhD [a,b,1], Iman Dianat PhD [a,*], Alex Stedmon PhD [c,2]

[a] Department of Occupational & Environmental Health, School of Public Health and Nutrition, Tabriz University of Medical Sciences, Attar Nishabouri – Golgasht St., Daneshgah St., Tabriz 51666, Iran
[b] National Public Health Management Center (NPMC), Tabriz University of Medical Sciences, Tabriz, Iran
[c] Human Factors Research Group, Faculty of Engineering, University of Nottingham, University Park, Nottingham NG7 2RD, UK

ARTICLE INFO

Article history:
Received 31 January 2010
Received in revised form
26 May 2010
Accepted 16 August 2010

Keywords:
Carbon monoxide (CO)
Poisoning
Gas appliances
Public health

ABSTRACT

This paper describes the epidemiology of unintentional carbon monoxide (CO) poisoning in Northwest Iran between 2003 and 2008. Data were obtained from the records of the main provider of emergency medical transportation and from death certificate reports of the Legal Medicine Organization. During the study period, a total of 3078 hospital admissions were recorded against which 346 deaths were due to unintentional CO related poisoning caused by gas appliances in the homes. The ratio of unintentional CO related poisoning cases in relation to all poisonings was 11.6%. With regard to gender differences, non-fatal CO poisoning was higher in females than males, whereas actual fatalities were higher in males than females. Non-fatal CO poisoning was most prevalent in adults aged between 20 and 49 years, whereas the age specific death rate was highest for those over 60 years. The highest frequency of both non-fatal poisonings and actual fatalities occurred in the month January. The results suggest that CO poisoning has a high prevalence in this geographic region, with elderly adults being at the greatest risk, especially during the winter season. This represents a serious, but often neglected area of public health, and Health Authorities should be encouraged to promote public awareness against the dangers of CO exposure. This paper reviews the data and evidence surrounding the issue of CO poisoning and makes recommendations that a range of agencies and authorities should be involved in setting stricter standards and environmental legislations in this respect.

1. Introduction

Carbon monoxide (CO) is a colourless, odourless, and non-irritating gas produced as a result of incomplete combustion of carbon-based fuels.[1] Exposure to CO can be extremely harmful to human health with the early effects of poisoning often going unnoticed. The early symptoms of acute CO poisoning include headache, dizziness, weakness, nausea, confusion, disorientation, and visual disturbances,[2] which can be easily confused with general ill-health. However, in extreme cases, poisoning leads to unconsciousness, coma, convulsions and even the death of an individual.[2] CO poisoning therefore represents a serious health threat on a global level. In the United States, it has been estimated that approximately 50,000 annual emergency department visits are due to CO poisoning[2] which may also be responsible for more than half of all fatal poisonings reported in many countries each year.[3] Mortality rates from CO poisoning in the United States were 8.8 deaths per million people in 1998.[4] However, as the symptoms of CO poisoning are non-specific and variable, it is difficult to detect or diagnose the effects,[5] and therefore, poisoning cases may be misreported and therefore severely underestimated.[2]

As natural gas is a primary source of domestic energy for many areas of the world, the most common sources of CO are faulty, poorly maintained or inadequately ventilated gas appliances such as stoves and heaters.[6] The use of such appliances is often widespread and demand increases during periods of cold weather and, in particular, through winter months. The climate in Northwest Iran is generally cold, and in winter there is frequent heavy snowfall and sub-zero temperatures. In line with the rest of the world, natural gas is the main energy source for domestic heating in this region of the country. With such widespread use of gas appliances and the potential dangers they represent, the characteristics of CO poisoning in Iran are still largely unknown as any epidemiological studies or analyses are rare. In an attempt to address this and investigate this major issue of public health, the present study was conducted in order to describe the epidemiology of unintentional

* Corresponding author. Tel.: +98 937 5778072; fax: +98 411 3340634.
E-mail addresses: nazari_j@yahoo.com (J. Nazari), im_dianat@yahoo.com (I. Dianat), alex.stedmon@nottingham.ac.uk (A. Stedmon).
[1] Tel.: +98 935 9730347; fax: +98 411 3340634.
[2] Tel.: +44 (0) 115 9514068.

1752-928X/$ – see front matter © 2010 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2010.08.003

CO related poisoning caused by gas appliances in the East Azerbaijan province in Northwest Iran and therefore represents one of the largest studies of its kind for this region.

2. Method

The study focussed on the East Azerbaijan province of Northwest Iran including its fifteen districts. East Azerbaijan province occupies about 47,830 square meters of the country. It has an estimated population of 3.6 million, accounting for approximately 5.1% of the Iran's total population. Data were analysed across a five year period, from 21 March 2003 to 20 March 2008 (based on Iran's calendar year).

To identify incidents of CO poisoning, the authors reviewed all medical records of the patients transported by the emergency medical service (EMS) system in which a person received a diagnosis of unintentional CO related poisoning. At the time of the study, the EMS operated 47 ambulance dispatch centres throughout the East Azerbaijan province and had a fleet of 61 ambulances. The EMS is the first respondent to most medical emergencies, providing rapid transport to the nearest appropriate hospital. Fatalities from CO poisoning for all East Azerbaijan residents were extracted from death certificate reports of the Legal Medicine Organization. Cases of unintentional CO poisoning related deaths were classified based on the International Classification of Diseases, Tenth Revision (ICD-10) codes T58 and X47. Deaths caused by intentional exposure, exposure of undetermined intent or fire-related exposure to CO were excluded from the study. From the records, the data were analysed by: annual trends, gender, age, occupational status, the month and location in which the unintentional CO related incident occurred, as well as the outcome of treatment (non-fatal or fatal). Census data for the year 2006 were used to calculate the rates per 100,000 inhabitants of the East Azerbaijan province.

3. Results

3.1. Overview

During the 5 year investigation period, a total of 3078 people were diagnosed with non-fatal CO poisoning, representing a total of 2097 unintentional CO exposure incidents recorded in the same period. During this period, 346 deaths were confirmed due to CO exposure, resulting from 237 exposure incidents (illustrated in Table 1). The proportion of unintentional CO related poisoning compared to all other cases of poisoning was 11.6%.

Table 1
Frequencies of study variables.

Variables	Non-fatal Number (%)	Fatal Number (%)
Gender		
Male	1176 (38.2)	185 (53.5)
Female	1902 (61.8)	161 (46.5)
Age (years)		
0–9	344 (11.1)	43 (12.4)
10–19	441 (18.6)	51 (14.7)
20–29	785 (25.5)	76 (22.1)
30–39	605 (16.4)	43 (12.4)
40–49	362 (10.6)	52 (15.0)
50–59	272 (9.0)	47 (13.6)
60<	269 (8.8)	34 (9.8)
Location		
Urban	2893 (94.0)	309 (89.3)
Rural	185 (6.0)	37 (10.7)
Total	3078 (89.9)	346 (10.1)

3.2. Annual trends

The number of non-fatal CO poisonings increased during the study period from 436 reported in 2004, to 642 reported in 2008 (illustrated in Fig. 1). In the same period, the number of fatalities from CO poisoning increased from 30 in 2004, to 59 in 2008 (the mean fatality rate was 69 deaths per year). The highest number of poisonings occurred in 2007 with 936 non-fatal poisonings and 94 fatalities.

3.3. Gender

Males accounted for 1176 cases (38.2%) of non-fatal poisonings and 185 cases (53.5%) of actual fatalities. Females represented 1902 cases (61.8%) of the non-fatal poisonings and 161 fatalities (46.5%). The death rate was slightly higher for males (9.8/100,000) than females (8.8/100,000).

3.4. Age

Non-fatal CO poisoning was most prevalent in the adult population (e.g. 20–49 year olds) of the East Azerbaijan province (illustrated in Fig. 2). During the investigation period, there were 785 cases of non-fatal poisonings among 20–29 year olds, 605 cases among 30–39 year olds and 362 cases among 40–49 year olds.

The death rate from CO poisoning was highest in individuals aged 60 and over (13/100,000 or 34 deaths) compared to other age groups at risk of death by CO such as 20–29 year olds (9/100,000 or 76 deaths), 30–39 year olds (8/100,000 or 43 deaths) and 40–49 year olds (7/100,000 or 52 deaths). The lowest incidence of non-fatal poisonings and fatalities were observed among 1–9 year olds.

3.5. Occupational status

The death rate from CO poisoning based on the occupational status of the victims is presented in Table 2. The occupation with the highest incidence of CO poisoning was that of housekeeper (accounting for 33.8% of the total recorded deaths), followed by manual workers (who accounted for 27.5% of the total recorded deaths). Interestingly the housekeeper deaths were solely female workers and the manual worker deaths were solely male workers.

3.6. Month

The highest frequency of non-fatal poisonings occurred in the months of January and February with 717 cases (23.3%) and 615 cases (20%), respectively (illustrated in Fig. 3). The lowest number

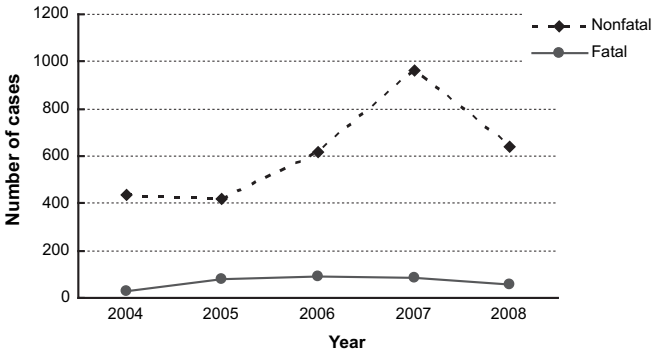

Fig. 1. Non-fatal and fatal poisonings due to unintentional CO exposure from 2003 to 2008.

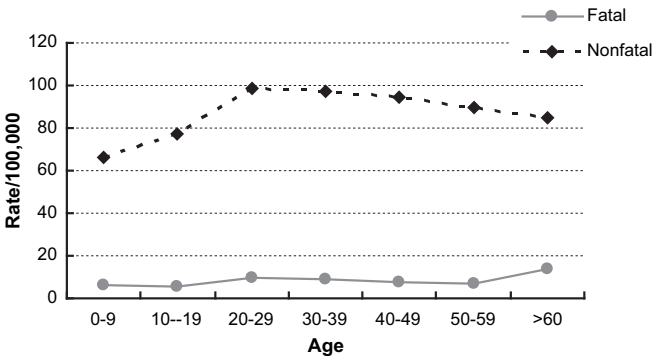

Fig. 2. Age-specific rates of non-fatal and fatal poisonings from unintentional CO exposure from 2003 to 2008.

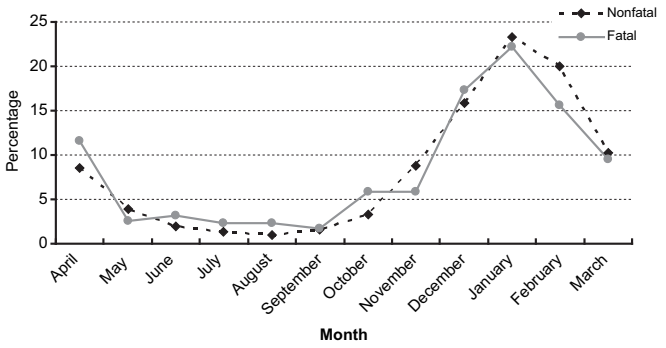

Fig. 3. Cases of non-fatal and fatal poisonings due to unintentional CO exposure recorded per month from 2003 to 2008.

of non-fatal poisonings occurred in August with 31 cases (1%). Similarly, the number of fatalities due to CO poisoning was highest in January with 77 cases (22.2%) followed by December with 60 cases (17.3%). The lowest number of deaths occurred in September with 6 cases (1.7%).

3.7. Location of incidents

The majority of non-fatal poisonings (94%) and actual fatalities (89%) occurred in urban rather than rural areas.

4. Discussion

Non-fatal and fatal poisonings from CO exposure in the East Azerbaijan province in Northwest Iran between the period of 2003 and 2008 were analysed in this study. More specifically, data were examined for unintentional, non-fire related, CO poisoning caused by gas appliances in domestic homes. Over the 5-year study period, unintentional CO exposure was attributed to 3078 non-fatal poisonings and 346 deaths. The ratio of CO poisoning cases to all poisonings in this study was approximately half of that reported in other related research.[7] The results indicated that the incidence of CO poisoning increased between 2003 and 2007. According to official data held by the East Azerbaijan Gas Company, the number of dwellings connected to the gas distribution network in this region increased from 530,889 homes in 2003–710,301 homes in 2007 (an approximate increase of 20%). Therefore, the increased incidence of CO poisoning during this period may, in part, be attributable to the increase in the number of households connected to the gas network. This could mean that as new homes are connected to the gas network, users are not fully aware of the dangers or do not properly maintain gas appliances in their homes.

The finding that more incidents of non-fatal CO poisoning occurred in individuals between the ages of 20 and 49 years suggests that this group of users are at greater risk of poisoning than other groups. However, as this study has shown, elderly people are at a greatest risk of death by unintentional CO related poisoning, which is consistent with previous research conducted in the United States,[8] and in the UK.[5] Elderly people are at greater risk possibly due to their limited mobility and poorer economic situations which may impact on how regularly they maintain appliances themselves or in their ability to afford for professional maintenance. In addition, higher death rates in elderly users have been associated with the likelihood of mistaking CO poisoning for symptoms of other common ailments such as influenza-like illnesses or fatigue.[9] Other research has suggested that elderly users are more likely to succumb to CO poisoning due to poorer cardiovascular activity and pulmonary reserve.[8,10]

Table 2
Fatal poisoning from CO based on the occupational status of the victims.

Occupation	Men Number (%)	Women Number (%)	Total Number (%)
Housekeepers	0 (0)	117 (72.7)	117 (33.8)
Manual workers	95 (51.4)	0 (0)	95 (27.5)
Office workers	26 (14.1)	6 (3.7)	32 (9.2)
Retired	16 (8.6)	0 (0)	16 (4.6)
Students	10 (5.4)	3 (1.9)	13 (3.8)
Drivers	10 (5.4)	0 (0)	10 (2.9)
Others	28 (15.1)	35 (21.7)	63 (18.2)
Total	185 (100)	161 (100)	346 (100)

Although females were almost twice as likely to visit an emergency department for CO exposure, males were at greater risk of death by CO poisoning than females. The incidence of higher death rates in males have been reported in other research and this research supports the trend of higher death rates in men.[8,11] Other research has suggested that the higher rate of death in men may be attributable to them participating in more high-risk behaviours than women (such as working with fuel-burning tools or appliances)[9] or that they may be more likely to work in high-risk manual activities with prolonged CO exposure (such as repairing and maintaining appliances).[8] The results of this current research suggest that the risk of death from CO poisoning is greatest among men engaged in manual work. Interestingly, the female occupation with the highest incidence of death from CO poisoning was for housekeepers. This further supports the observation that men might participate in more risky activities but also that women might traditionally work in occupations in domestic environments which have faulty gas appliances. These results illustrate that the mechanisms and causes of CO exposure are still not fully understood and that this should be the focus of the future research.

CO poisoning occurred mostly during the winter months (December, January and February) which supports other research findings.[5,12] This finding is, perhaps, to be expected as domestic gas appliances are likely to be used more often in colder weather conditions, exacerbating the potential for unintentional CO related poisoning in confined spaces or in poorly ventilated areas which perhaps are kept closed and as draft free as possible at this time of year.

As this research has illustrated, the incidence of unintentional CO related poisoning is largely seasonal, with specific age groups of the population at the greatest risk. This suggests the need for better public education and preventive messages about potential hazards of CO exposure through the media, especially during winter season. This information should be communicated in a suitable medium

(television, radio, internet, etc) for the target population and in an easily understandable form. Special care should be taken in distributing such information by alternative methods (e.g. public announcements) for people who do not have access to mainstream media.[13] In addition, a range of agencies such as local authorities and gas suppliers should be involved in setting up stricter standards and environmental legislations to cover the potential dangers of unintentional CO related poisoning. More specifically, a major concern of health authorities should be the promotion of public awareness about the potential hazards, and prevention, of CO exposure in the domestic environment.[6]

Given the numbers of deaths associated with unintentional CO related poisoning, it is largely preventable through simple precautions such as proper installation and maintenance of gas appliances. Gas appliances in households should be checked annually by registered gas installers; flues and chimneys should be kept clean and checked for blockages; and adequate ventilation should be maintained especially in colder weather and through the winter season. A range of affordable visual and audible CO detectors are available that can warn occupants of dangerous levels of CO in their homes or work environment. There should be a greater awareness about the benefit of these detectors, more effort to promote their use. A combination of environmental legislation, improved standards and continuous educational efforts could all help to reduce the incidence of unintentional CO related poisoning in the future.

Although this investigation makes a number of important observations from the data, the true number of cases for non-fatal CO poisoning in the East Azerbaijan province over the period of this study may not be known. The data for non-fatal poisonings are based on victims transported to hospitals and treated in emergency departments and do not include those treated in outpatient settings or those not treated at all. As a result the true impact of this kind of poisoning is likely to be higher. In addition, some cases of CO poisoning may not be diagnosed correctly as the symptoms are non-specific and may be easily confused with viral ailments (such as an influenza-like illness).[1] Therefore, these situations are likely to lead to an underestimation of incidents.

5. Conclusion

There are clear patterns to the incidence of unintentional CO related poisoning in Northwest Iran. More often than not, the incidence is non-fatal but a proportion of cases are fatal. Understanding the epidemiology of this phenomenon is a valuable tool to focussing resources and raising awareness of what is generally a preventable situation. Preventive measures and public education about CO exposure are required to reduce the future incidence of unintentional CO related poisoning. In addition, future studies are required to investigate the causes and mechanisms of CO exposure to underpin public health and to plan appropriate interventions.

Acknowledgements

This project was funded by the East Azerbaijan Gas Company. The principal author wishes to acknowledge the support and assistance provided by the National Public Health Management Centre (NPMC) and the Emergency Medical Service (EMS) system at Tabriz University of Medical Sciences. The authors are indebted to the anonymous reviewers of this paper who offered valuable and constructive feedback.

Conflict of interest
None declared.

Funding
None declared.

Ethical approval
None declared.

References

1. Kao LW, Nanagas KA. Carbon monoxide poisoning. *Emerg Med Clin N Am* 2004;**22**:985–1018.
2. Hampson NB, Weaver KL. Carbon monoxide poisoning: a new incidence for an old disease. *Undersea Hyper Med* 2007;**34**(3):163–8.
3. Raub JA, Nolf MM, Hampson NB, Thom SR. Carbon monoxide poisoning—a public health perspective. *Toxicology* 2000;**145**:1–14.
4. Mott JA, Wolf MI, Alverson CJ, Macdonald SC, Bailey CR, Ball LB, et al. National vehicle emission policies practices and declining US carbon monoxide-related mortality. *JAMA* 2002;**288**:988–95.
5. Wilson RC, Saunders PJ, Smith G. An epidemiological study of acute carbon monoxide poisoning in the West Midlands. *Occup Environ Med* 1998;**55**:723–8.
6. Stefanidou M, Athanaselis S, Koutselinis A. Carbon monoxide: old poison-recent problems. *Leg Med* 2003;**5**(4):253–4.
7. Malangu N. Acute poisoning at two hospitals in Kampala–Uganda. *J Forensic Leg Med* 2008;**15**:489–92.
8. Cook M, Simon PA, Hoffman RE. Unintentional carbon monoxide poisoning in Colorado, 1986 through 1991. *Am J Public Health* 1995;**85**:988–90.
9. Centre for Disease Control (CDC). Carbon monoxide-related deaths—United States, 1999–2004. *MMWR* 2007;**56**:1309–12.
10. Meridith T, Vale A. A carbon monoxide poisoning. *Br Med J* 1998;**296**:77–9.
11. Cobb N, Etzel RA. Unintentional carbon monoxide-related deaths in the United States, 1979–1988. *J Am Med Assoc* 1991;**266**(5):659–63.
12. Ait El Cadi M, Khabbal Y, Idrissi L. Carbon monoxide poisoning in Morocco during 1999–2007. *J Forensic Leg Med* 2009;**16**:385–7.
13. Daley WR, Smith A, Paz-Argandona E, et al. An outbreak of carbon monoxide poisoning after a major ice storm in Maine. *J Emerg Med* 2007;**18**(1):87–93.